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LXXII. *An Attempt to assign the Cause, why the Sun and Moon appear to the naked Eye larger when they are near the Horizon. With an Account of several natural Phænomena, relative to this Subject. By Mr. Samuel Dunn.*

Chelsea, January 27, 1762.

Read Feb. 11, 1762. I. **T**HE Sun and Moon, when they are in or near the horizon, appear to the naked eye of the generality of persons, so very large in comparison with their apparent magnitudes, when they are in the zenith, or somewhat elevated, that several learned men have been led to enquire into the cause of this phænomenon, and, after endeavouring to find certain reasons, founded on the principles of physics, they have at last pronounced this phænomenon as a mere optical illusion.

2. The principal dissertations, which I have hitherto seen, conducing to give any information on this subject, or helping to throw any light on the same, have been those printed in the Transactions of the Royal Society, the Academy of Sciences at Paris, the German Acts, and Dr. Smith's Optics; but as all the accounts, which I have met with in these writings, any way relative to this subject, have not given me that satisfaction which I have desired, curiosity has induced me to enquire after the cause of this singular phænomenon, in a manner somewhat different from that which others have done before me, and by such experiments

experiments and observations as have appeared to me pertinent; some of which have been as follows; viz.

3. I have observed the rising and setting Sun, near the visible horizon, and near rising grounds elevated above the visible horizon about half a degree, and found him to appear largest when nearest to the visible horizon; and particularly a considerable alteration of his appearance in magnitude and light has always appeared to me, from the time of his being in the horizon at rising, to the time of his being a degree or two above the horizon, and the contrary at his setting; which property I have endeavoured to receive as a prejudice, and an imposition on my sight and judgment, the usual reasons for this appearance.

4. I have also observed, that the Sun near the horizon appears to put on the figure of a spheroid, having its vertical diameter appearing to the naked eye shorter than the horizontal diameter, and, by measuring those diameters in a telescope, have found the vertical one shorter than the other.

5. I have made frequent observations and comparisons of the apparent magnitude of the Sun's disk, with objects directly under him, when he has been near the horizon, and with such objects as I have found, by measurement, to be of equal breadth with the Sun's diameter; but, in the sudden transition of the eye from the Sun to the object, and from the object to the Sun, have always found the Sun to appear least; and that when two right lines have been imaginarily produced, by the sides of those equal magnitudes, they have not appeared to keep parallel, but to meet beyond the Sun.

6. From these, and other like circumstances, I first began to suspect, that a sudden dip of the Sun into the horizontal vapours, might, some how or other, be the cause of a sudden apparent change of magnitude, although the horizontal vapours had been disallowed to be able to produce any other than a refraction in a vertical direction; and reducing things to calculation, found, that, from the time when the Sun is within a diameter or two of the horizon, to the time when he is a semi-diameter below the horizon, the Sun's rays become passable through such a length of medium, reckoning in the direction of the rays, that the total quantity of medium, (reckoning both depth and density) through which the rays pass, being compared with the like total depth and density through which they pass, at several elevations, it was proportionable to the difference of apparent magnitude, as appearing to the naked eye.

7. This circumstance of sudden increase and decrease of apparent magnitude, and as sudden decrease and increase of light, (for they both go together) seemed to me no improbable cause of the phenomenon, although I could not then perceive how such vapours might contribute toward enlarging the diameter of the Sun apparently in a horizontal direction.

8. I therefore examined the Sun's disk again and again, by the naked eye, and by telescopes, at different altitudes, and, among several circumstances, found the solar maculæ appear larger and plainer to the naked eye, and through a telescope, the Sun being near the horizon, than they had appeared the  
same

same days, when the Sun was on the meridian, and to appearance more strongly defined, yet obscured.

9. A little before sun-setting, I have often seen the edge of the Sun with such protuberances and indentures, as have rendered him, in appearance, a very odd figure; the protuberances shooting out far beyond, and the indentures pressing into, the disk of the Sun, and always through a telescope magnifying fifty-five times, the lower limb has appeared with a red glowing arch beneath it, and close to the edge of the Sun, whilst the other parts have been clear.

10. At sun-setting, such protuberances and indentures have appeared to slide or move along the vertical limbs, from the lower limb to the higher, and there vanishing, so as often to form a segment of the Sun's upper limb apparently separated from the disk, for a small space of time.

11. At sun-rising, I have often seen the like protuberances, indentures, and slices, above described; but with this difference of motion, that at sun-rising they first appear to rise in the Sun's upper limb, and slide or move downward to the lower limb; or, which is the same thing, they always appear at the rising and setting of the Sun, to keep in the same parallels of altitude, by the telescope. This property has been many times so easily discernible, even by the naked eye, that I have observed the Sun's upper limb to shoot out towards right and left, and move downward, forming the upper part of the disk an apparent portion of a lesser spheroid than the lower part at rising, and the contrary at setting. Through the telescope, this has appeared more plain, in proportion to the power of magnifying.

12. These protuberances and indentures, so easily measurable by the micrometer, whilst the telescopic wires appeared strait, enabled me to conclude, that certain strata of the atmosphere, having different refractive powers, and lying horizontally across the conical or cycloidal space traced out by the rays, between the eye and that part of the atmosphere first touched by the rays, must have been the cause of such apparent protuberances and indentures, in an horizontal direction, across the Sun's vertical limbs; and also, that the bottoms of those protuberances and indentures must be considerably enlarged, and removed, to appearance, farther from the center of the disk, than they would have been, had there been no such strata to refract.

13. Before sun-rising, when the Sun has been near the tropic, and the sky, at the utmost extent of the horizon, hath appeared very clear, and when certain fogs have appeared in strata placed alternately between the hills, and over intervening rivers, vallies, &c. so as to admit a sight of the rising Sun over those fogs, I have often observed, with admiration, the most distant trees and bushments, which at other times have appeared small to the naked eye, but whilst the Sun has been passing along a little beneath the horizon, obliquely under them, just before sun-rising, when the Sun has been thus approaching towards and beneath any trees and bushments, they have grown apparently very large to the naked eye, and also through the telescope; and they have lost that apparent largeness, as the Sun has been past by them. Thus, a few trees standing together on rising ground, at the distance of a few miles, have appeared to grow up  
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into an apparent mountain. Such apparent mountains formed from trees, put on all forms and shapes, as sloping, perpendicular, overleaning; but soon recover their natural appearance, when the Sun is past by them, or got above the horizon.

14. Mountains themselves, at a distance, sometimes appear larger than at other times. Beasts and cattle in the midst of, and being surrounded with, water, appear nearer to us, than when no water surrounds them. Cattle, houses, trees, all objects on the summit of a hill, when seen through a fog, and at a proper distance, appear enlarged. All bodies admit of larger apparent magnitudes, when seen through some mediums, than others.

But more particularly,

15. I took a cylindrical glass vessel, about two feet high, and having graduated its sides to inches, I placed it upright on a table, with a piece of paper under the bottom of the glass, on which paper were drawn parallel right lines, at a proper distance from each other; and having placed a shilling at the bottom of the vessel, it was nearly as low as the paper. Pouring water into the vessel, and viewing the shilling through the medium of water, with one eye, whilst I beheld with the other eye, where the edges of the shilling were projected on the paper, and its parallels, I found the shilling appear larger, at every additional inch depth of the water; and this was the case, if either eye was used; and the same, when the eye was removed far from the surface, or near to it, or in any position thereto.

16. I took large vessels, filled them with water, placed different bodies at the bottoms of those vessels.

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It always followed, that the greater depth of the water I looked through, in the direction from my eye, to the objects in the water, the nearer those objects appeared to me. Thus light bodies appeared more mellow and faint, and dark bodies rather better defined, than out of the water, when they were not deeply immersed. And thus they appeared under whatever directions or positions I viewed the bodies.

17. I placed different bodies in proper vessels of fair water, and immersed my face in the water; viewing the bodies in and through the water, they all appeared to me plain, when not too far from the eye, and although a little hazy at the edges, they appeared much enlarged, and always larger through a greater depth of water. Thus, a shilling appeared nearly as large as half a crown, with a red glowing arch on that side opposite to the Sun, when the Sun shined on the water. From this experiment, I concluded, that divers see light objects not only larger, but very distinctly in the water.

18. These, and several other circumstances, being considered, they left me with but little doubt, whether the atmosphere refracts horizontally or not, as the afore-mentioned protuberances in the Sun's limb must have been wholly owing to such a cause, and the nearly allied strata in the atmosphere. That the apparently formed mountains of trees and bushments at sun-rising, so easily comparable with other trees and bushments of equal magnitude at other times, but in their affected state as much larger, must also be owing to the same cause. That seeing the nature and properties of those strata of horizontal vapours cannot differ from each other, as much as the whole quantity of  
medium,



medium, through which a ray of light passeth in coming from the horizontal Sun, differs from the whole quantity of medium, through which another ray of light passeth in coming from the vertical Sun; and the latter experiment being so consonant to the manner in which the rays of light pass, through the medium of the atmosphere, into the eye; I therefore concluded, that these were proofs, that objects seen through a medium of greater depth, or density, do appear more large; and that therefore, not only the Sun and Moon, but that all other objects, seen at great distances, under an horizontal direction, do appear larger to the naked eye, than objects of equal magnitude and distance do appear, when seen under a vertical direction.

19. Although the quantity of medium, with its density, be here mentioned, as though it was the efficient cause of this effect, possibly it may be some other cause in the horizontal vapours, water, and other mediums, which produceth effects nearly proportionate to the difference arising from a comparison of the quantity of medium, or density. Whether this effect arises from density or rarity, reflection, refraction, or inflection, acceleration, retardation, or absorbency of the rays, seems to me to deserve a proper enquiry. What others may find to be the cause of these phenomena, I cannot determine; to me it has seemed most natural, that the rays, under the foregoing circumstances, first become obstructed, and many of them wholly absorbed, the rest proceeding with a retarded motion, are thereby first more reflected, and then less refracted through the humours of the eye; and lastly, the image on the retina becomes hereby  
enlarged.

enlarged. In other words, certain accidents making the rays more divergent than they otherwise would be, at their entrance into the eye, seem to me to be the cause of these and other like appearances.

20. On any evening, when the sky is very clear and serene, and the Moon high, if the sky near the horizon, all around, be observed, it will appear, to the naked eye, more white and light than any other part, except that part of the sky which is near to the Moon. The like is observable, when the Moon doth not shine. This seems to prove, that when the Moon's light has fallen promiscuously on the vapours of the atmosphere, it is more copiously reflected from the vapours near the horizon, than from those in a direction toward the zenith. And thus, it seems, they must, in proportion to the depth and density of the one, compared with the depth and density of the other. The same seems to be confirmed, by the burning of a candle, or other light, in a fog; for, then, it appears to give a stronger blaze of vaporous light, within that certain sphere it illuminates, than it doth in true permanent air, and yet the rays extend farther in the latter case, than in the former.

21. When a number of candles, lamps, torches, or other lights, are placed at equal distances from each other, in a row a mile or two in length, and a spectator stands at one end of the row, viewing those lights, the nucleus of the nearest light will appear whitest and brightest, and best defined; but looking onward to the rest, they will appear more and more red, dull, and faint, the farthest will not appear largest, nor the nearest, but some intermediate one, at a certain distance from the nearest. Hence there

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is a maximum of the apparent magnitude of the nucleus, as seen by the naked eye.

22. Among the fixed stars, may be observed a diversity of colour and splendour, somewhat like that diversity, which is observable among those terrestrial lights. Some fixed stars are more sharply defined than others, such are generally white, and their vibratory scintillations more quick and smart. Others, which twinkle more slowly, are generally more red and large. In the zenith, they appear almost all of them entirely free from twinkling; and in the horizon, they are so invellaped in vapours, as to be undiscernible; at their first appearance after rising, or last appearance before setting, they twinkle more slow. It seems, therefore, not only probable, that the atmosphere is the cause of their apparent scintillations; but that, could the distance of one fixed star be obtained, the distances of some others might be essayed at, by analogy of their colours, and vibratory scintillations. Possibly also, we may acquire some knowledge of the nebulous stars, from like considerations.

23. For the reasons which have been communicated, it has appeared to me, that the Sun and Moon, and distances of stars near the horizon, do appear enlarged to the naked eye; because they then appear nearer to us. That they then appear nearer to us, and more faint; because then their rays pass through a greater length of the atmosphere and horizontal vapours. That in so passing through a greater length of the atmosphere and horizontal vapours, those rays are so reflected, refracted, inflected, attracted, resisted, accelerated, or retarded, so as to become more divergent than they otherwise would, at their entrance into

the eye. That as a consequence hereof, that part of the sky which is near the horizon, appears nearer to us than that part near the zenith. That the apparent nearness of the sky near the horizon, is always in a certain, though variable proportion, to the state and properties of the horizontal vapours. That as objects appear larger and nearer, when they are near the horizon, than when they are near the zenith, so they appear larger through the medium of the atmosphere, than they would through a space devoid of air. That the alteration of the foci of optic glasses, in order to adapt them for remote or near distances, is chiefly dependant on the same cause, as that which produces the foregoing effects. That this cause may be investigated by proper experiments and considerations. That herefrom, possibly, the resistance of the æther beyond the regions of our atmosphere, and the proportional distances of the fixed stars, may be essayed at, with other matters of curiosity, import, and utility.

24. The phænomena of nebulous and new stars, have engaged the attention of curious astronomers; but none, that I know of, have given any reasons for the appearance of nebulous stars. Possibly, what has been before advanced, may also be applicable, for investigating reasons for those strange appearances in the remote parts of the universe.

From many instances, which might be produced, concerning the nature and properties of lights and illuminations on the Earth's surface, concerning the nature and properties of the Earth's atmosphere, and concerning the atmospheres and illuminations of comets, we may safely conclude, that the atmospheres

of comets, and of our Earth, are more gross in their nature, than the ætherial medium, which is generally diffused throughout our solar system. Possibly a more aqueous vapour in the one than in the other, makes the difference. Now, as the atmospheres of comets and planets, in our solar system, are more gross than the æther, which is generally diffused throughout our solar system, why may not the ætherial medium diffused throughout those other solar systems, (whose centers are their respective fixed stars) be more gross than the ætherial medium diffused throughout our solar system? This is, indeed, an hypothesis, but such an one as agrees exactly with nature. For those nebulous stars appear so much like comets, both to the naked eye and through telescopes, that the one cannot always, by any difference of their extraneous light, be known from the other.

Such orbs of gross æther, reflecting light more copiously, or like the atmospheres of comets, may help us to judge of the magnitudes of the orbs illuminated by those remote suns, when all other means seem to fail.

The appearance of new stars, and disappearance of others, possibly, may be occasioned by the interposition of such an ætherial medium, within their respective orbs, as either admits light to pass freely, or wholly absorbs it at certain times, whilst light is constantly pursuing its journey, through the vast regions of space.